THE MODE IN WHICH COCKROACHES AND EARWIGS FOLD THEIR WINGS.

BY SAMUEL H. SCUDDER.

SEVERAL years ago, Dr. Henri de Saussure, of Geneva, published, under the title of Études sur l'Aile des Orthopteres,[1] some interesting observations on the structure of the wings of cockroaches. He treated particularly of the folding of the wings in those groups of Blattarians where the wing is very ample and some contrivance necessary to insure its complete protection by the smaller wing-covers. The necessity of some peculiar arrangement in the winged genera of earwigs, where the extended wing is often ten times larger than the wing-covers (tegmina) is even more evident; and to understand the nature of the structural modifications of a normal wing-type (which are here universal), it will be convenient and instructive to examine the cockroach's wing on the basis of Saussure's memoir, for in different genera of this group we have every stage of change from simple unreversed wings scarcely larger than the tegmina, to those of great size, curious complication, and unique mode of duplicature.

In the hind wings of all Orthoptera, the anal area, or the area traversed by the nervules of the posterior part of the wing, is unusually ample; the branches of the anal vein are numerous and straight, and originate not far apart nor far from the base of the wing; when the wing is fully expanded they diverge like the rays of a fan; and like a fan they fold themselves against the sides of the body, the membrane of the wing folding along an edge midway between each pair of rays; this admits of a large expansion of the anal field, and provided the wings are not quite so long as the tegmina, any breadth, folded close, may be covered by this coriaceous appendage. This, however, would not necessarily be true, if the anterior part of the wing, provided with stiff interlacing veins, were itself as broad as the tegmina; for then, if the front edges of the wings and tegmina were brought together, the entire folded anal area would extend beyond the opposite margin of the wing, quite unprotected by the tegmina; to obviate this, the line of separation between the anal area and the anterior part of the wing is itself an axis of duplicature, and the folded anal area always lies beneath the stiff anterior parts of the wing.

[1] Annales Sc. Nat. [5] Zool. x. 161–200, plate 11.

This is a mode of duplicature common to all groups of Orthoptera. But we have in cockroaches and earwigs something superadded, where the wing is large, and folded not only longitudinally but transversely, and is ingeniously packed away beneath the shorter tegmina. We will follow Saussure in tracing among the cockroaches the various steps from the simple to the complex form.

As usual among insects, the anal field of the hind wing in cockroaches (Figure 29, r [1]) does not generally extend much more than half way toward the tip of the wing; and, as in most insects, especially those of low organization, the upper limit of this area (that separating it from the principal part of the wing, Figure 29, p) is marked at the edge of the wing by a slight emargination. The first step toward the result to be attained is the lengthening of the anal field so that it equals the anterior parts, bringing the indentation to the apex of the wing. This is seen in *Thorax porcellana* of the East Indies. There is, however, a little triangular bit of membrane left between this indentation and the lowermost nervule of the next vein above. It is to this little triangle that we must direct our attention. For in the next stage, such as is seen in a common European cockroach, *Ectobia lapponica*, this triangle has greatly enlarged; the principal longitudinal fold of the wing, that separating the anal area from the parts above, is obliged to run directly through the middle of this triangle, so that we may fairly consider one half as belonging to the anal and the other half to the median field of the wing. Since, however, it contains in itself no nervures and has become also of a more or less coriaceous texture, its posterior portion cannot take part in the plications of the anal field; moreover, it has expanded apically and now forms the entire tip of the wing, producing at its upper limit a slight excision of the edge similar to the normal emargination at its lower limit. When the anal field-fan is closed and lies at rest beneath the anterior part of the wing, this triangle, reduced to half its size by a single fold, lies beyond the edge of the wing, and either folds back again upon the upper surface of the wing or curls up in the same position and is thus

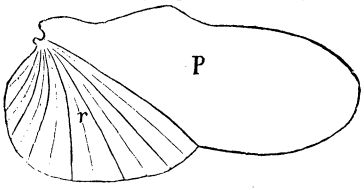

FIG. 29.

[1] Figures 29–40 have been generously forwarded by Dr. de Saussure for the illustration of this paper.

wholly concealed by the tegmina. When this triangle has enlarged still more, as in the East Indian *Prosoplecta coccinella* (Figure 30), the nervules on either side of it have been forced,

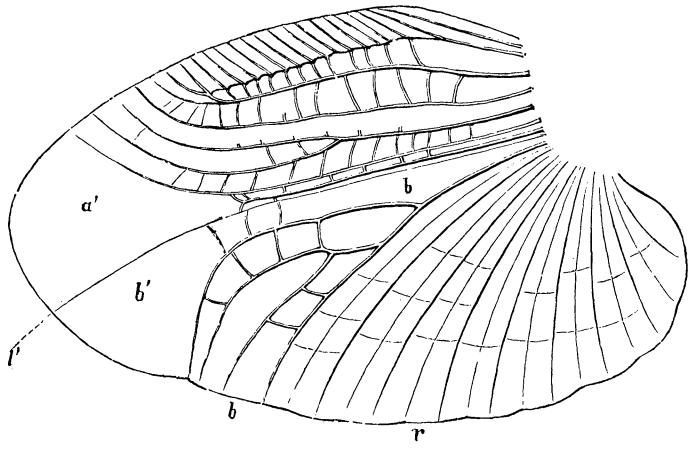

FIG. 30.

as it were, to curve upward or downward to give it room ; those below the triangle have undergone a still more remarkable modification to which we shall again allude. In further steps this triangle expands still more (Figure 31, *Plectoptera porcellana* of

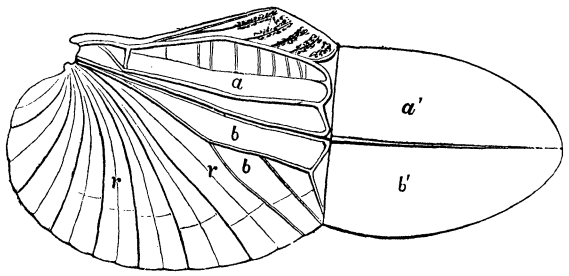

FIG. 31.

Cuba), throwing the veins on either side of it farther and farther back, until they fall into a single straight line at right angles to their former direction, one being turned upward, the other downward ; and as this line marks the crease where in *Ectobia lapponica* the triangle was folded back upon the top of the wing, so now the wing, having first been folded longitudinally throughout its entire length (the hinder portion lying beneath the upper), has its tip folded over, not far beyond the middle, upon the upper surface of the wing.

It may here be worth while, by the aid of diagrams, to explain a little more carefully the mode in which the wings are folded. Figure 32 may represent a fully expanded wing, such as that last described; *ab*, *a'b'* (*p* of Figure 29) may be called the principal part of the wing, and *r* the diverging field; the bent longitudinal line, separating the anterior zone (*aa'*) from the reversible zone (*bb'*) is the principal longitudinal fold of the wing, to which we have constantly referred; the straight line separating the basal (veined) portion of the wing (*ab*) from the apical (coriaceous) reflectible portion (*a'b'*) is the transverse fold, which in the simpler wings is represented by the upper and lower margins of the apical triangle. The diverging field (*r*) first folds like a fan, so that *b* and *r* together are no broader than *a*; the wing then folds longitudinally, *bb'* bending downward beneath *aa'*, and presents the appearance seen in Figure 33, where *a* and *a'* are alone visible; *a'* now bends upward and folds back upon *a*, as in Figure 34, and the wing is reduced to a little pad, which scarcely surpasses the basal portion of the anterior zone *a*.

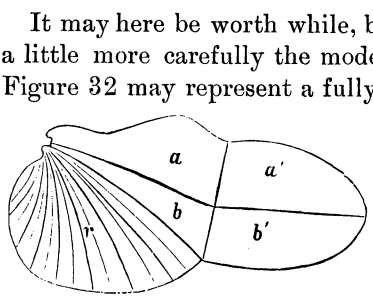

Fig. 32.

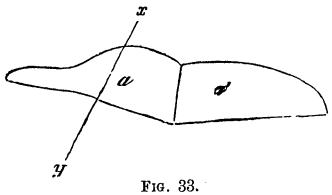

Fig. 33.

Figures 35 to 37, which represent a theoretical section of the wing along the line *xq* (Figure 33), will explain still further this mode of duplicature. In Figure 35 the wing is fully expanded, and *c* represents the costal, *z* the posterior border of the wing; *a*, *b* and *r* represent the same part as in Figure 32, *p* the longitudinal fold or plication separating the anterior from the reversible zone, and *g* the point of division between the reversible zone and the diverging field. In Figure 36 the first step is seen, namely, the result of the plication along the longitudinal fold *p*; Figure 37 (in which the letters bearing primes represent the same parts in the reflectible portion as the equivalent letters in the basal portion of the wing) carries the process to its completion. Figure 38 represents a horizontal section of the completely folded wing; *o* is the anterior, *o'* the posterior articulation of the wing; *o' v* represents the diverging field, *o' t'* the basal portion and *t' e'* the

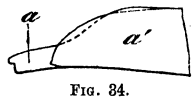

Fig. 34.

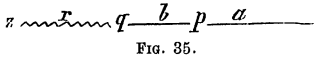

Fig. 35.

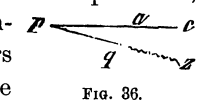

Fig. 36.

reflexible portion of the reversible zone; and *ot*, *te* the corresponding portions of the anterior zone.

There are further modifications of this duplicature; thus in some types, the anal field being ample, a simple fan-like closure of the anal area is not sufficient, and its whole mass is again folded longitudinally and lies not only beneath the under surface of the anterior part of the wing, but beneath the reversible zone or anterior part of the anal area. This may readily be seen on examining Figures 39 and 40 (cf. figures 36 and 37) in which the diverging field *r* or *qz* is bent upon *pq* and lies beneath all the other folds of the wing. Add to this the reversal of the tip of the wing, and by a single stroke of the knife, one may cut through five layers of membrane, not counting the fan-like plications of the anal area which might be severed.

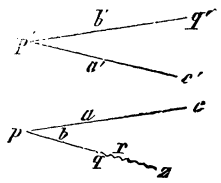

FIG. 37.

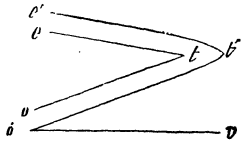

FIG. 38.

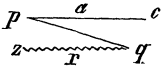

FIG. 39.

There is another curious fact; namely, that when the apical triangle has reached or nearly reached its maximum development, as in *Prosoplecta coccinella* (Figure 30) and *Plectoptera porcellana* (Figure 31), that portion of the anal field which lies within the transverse fold, and above a line drawn from the socket of the wing to a point near the anal emargination (*i. e.*, the basal portion of the reversible zone, *b*, *b*), assumes a venation precisely analogous to that of the upper half of the wing with all its distinct cross-veins and odd reticulations; this becomes possible because it is no longer folded with the rest of the anal field, and does not require simple longitudinal veins. When situated above the anal emargination its relation to the anal area is almost entirely disguised. Even further than this: in some types, as in the Australian *Diploptera silpha*, the terminal reversed area, a simple development of the apical triangle, is filled with a net-work of secondary veins, wholly similar to those of the parts toward the base, and in some instances (but for the transverse fold) direct continuations of them; were the steps unknown by which such a mode of wing-duplicature had been produced, and *Diploptera silpha* the sole living example of such duplicature, the structure of its wings would be utterly incomprehensible on

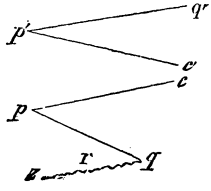

FIG. 40.

the hypothesis of any unity of type in the wing structure of insects.

But these later developments in the modification of the veins themselves have no bearing upon the structure of the wings of earwigs, and have only been introduced for their own interest and to complete the account we have given of duplicature in the wings of cockroaches. We may, however, keep the last statement before us when we recall the fact that the wings of all earwigs (so far as I have been able to determine after an examination of many types otherwise diverse) are identical in their general structure and wholly different from those of any other insects, having been extraordinarily modified to serve a special purpose.

In these insects the fore wings (tegmina) are always small and generally but little longer than broad, although earwigs are invariably slender, and the tegmina, to cover the abdomen, would need be very long. The wings, when folded, generally extend a little beyond the tegmina, and the parts which protrude are coriaceous and wholly devoid of veins; being moreover frequently ornamented with a colored spot or stripe, and thus further resembling the tegmina, they might be taken for a second pair of tegmina precisely like the first, or differing only in a slightly increased length; even if the tegmina are removed the deception remains, for the parts of the wings then exposed are coriaceous to the base. These wings, however, are quite as ample as those of other Orthoptera of equal size; but, by a complicated system of duplicature, accomplished by the mere elasticity of the parts, they are in a few seconds packed snugly beneath the pad-like tegmina, out of danger of abrasion or rupture, as the insect seeks the hidden recesses and crevices where it passes the larger part of its existence.

The most extraordinary thing about the structure of the wings is the immense extent of the anal area; not only does this reach from base to apex of the wing, as in the extreme type of cockroaches, but the entire wing, excepting only a portion about equalling the area of the tegmina, is made up of this field; the portion which does not belong to it is almost entirely coriaceous, so that nearly all the nervules of the wing belong to the anal vein. In the hind wings of Orthoptera in general, this anal vein may be roughly described as consisting of a basal arc to which the bases of the various rays are attached one beneath another; or, rather, the enlarged bases of these rays, lying one beneath

another, constitute the arc. This basal arc is closely attached to the lower articulation of the wing with the body in the other families of Orthoptera; but in the earwigs one of these veins, the second from the attachment (see Figure 41,[1] which represents

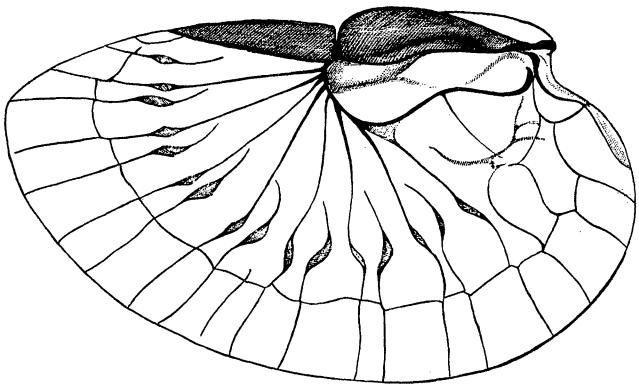

FIG. 41.

the wing of *Labidura riparia*, common in Europe and America) extends out nearly to the middle of the wing, emitting on the way one or two inferior branches; and, curving upward to the front border just beyond the coriaceous part of the wing (from which it is separated anteriorly by an incision), forms at this point, about the middle of the front border of the wing, the base for the attachment of the diverging rays, which sweep around the entire extent of the wing. The wing may then be said to have two bases; one the point of attachment of the whole structure to the body; the other, the pivot in mid-wing, around which the extensible major part of the wing plays. The radiating veins as well as the independent veins which arise between them, show a further peculiarity in having near the middle a considerable expansion, generally accompanied by an equivalent tenuity, so as to make the wing appear delicately coriaceous in a narrow circuit parallel to the outer border and about midway between it and the hinge or pivot in mid-wing. As to the other veins of the wing, their importance is too slight to be worthy of consideration in this connection; they occupy but a narrow area bordering the coriaceous base of the wing and are present only to an extent sufficient to indicate with certainty that it is the anal vein, to which the mass of nervules must be referred. The anomalous structure of the wing is at once seen on comparing it

[1] Which we owe to the kindness of Mr. Edward Burgess.

with the wing of a cockroach, its nearest ally, and the purport of the anomaly will appear when we examine carefully the closure of the wing.

Suppose this wing expanded to its utmost. It is retained in its place by muscles which act upon two sets of veins; an anterior set which supports the coriaceous base of the front part of the wing, giving a certain strength and solidity to the whole; and a posterior set which holds at arm's length, as it were, and therefore at great disadvantage, the body of the wing, hinging upon the extremity of the second anal branch which runs from base to mid-wing. Let the latter support be relaxed and the fan closes at once; the pivoting point is seen to be the very bottom of the incision of the wing next the apex of the coriaceous portion, an incision in the middle of the front border of the wing, corresponding to the anal emargination of the apex of the wings of certain cockroaches and to that of the middle of the hind border of most insects. When this fan of the anal field is closed, the plications are brought beneath that portion of the wing which lies between the extended vein which supports the rays and the lower edge of the coriaceous base of the wing. Since the coriaceous base does not extend quite to the middle of the expanded wing, the wing by this process is at once reduced to less than half its length; and the former apex for the same reason now overlaps the base and rests beside it against the body; the width of the wing being also reduced, the entire area is now less than one sixth its former extent. As the wing continues to close, the lower half, with its tightly plicated membrane, folds longitudinally beneath the coriaceous basal portion, so that the plications are completely encased, like leaves in a book, between a coriaceous upper layer and the thinner membrane of an equal portion of the wing lying, when the wing is expanded, directly behind it; the apex of the wing, however, now lies in even a worse position than before, directly beneath the root of the wing; or would do so, but having by this last movement been turned upside down, its elasticity allows another movement which its very position before prevented; and we now perceive the meaning of the expansion and tenuity of the radiating veins in points arranged in a circuit parallel to the outer border; on the folding of the wing these are brought together, and it is just here that the apex of the wing, which is apparently so much in the way, now bends transversely downward beneath the remainder of the wing, and the whole is reduced to less than a tenth, probably

less than a fifteenth, of its former extent. The anterior supports are now relaxed, the wing assumes its natural position, the wing-cover closes down upon it, and all is snugly packed away.

Although I have never experimented upon a living earwig, it will be apparent to any one who has attempted to expand a wing rendered flexible by artificial means, that the closure of the wing is produced by the mere elasticity of the parts. It is also altogether analogous to the process of duplicature in the cockroach, as carefully explained by Saussure, and it is difficult to explain the process in any other way. The mode in which they are opened would be much more difficult to understand if it had not been observed by Charpentier and described nearly forty years ago. The contraction of the extensor muscles attached to the hinder set of veins would undoubtedly cause the fan to expand when once the double folding, transverse and longitudinal, had been overcome; but it does not seem possible that they could cope with this difficulty. How then is it done? According to Charpentier, simply by means of the forceps with which the extremity of the abdomen is always provided in both sexes; the tip of the body is bent upward and the forceps used with great rapidity and ease, first on one side and then on the other, as a sort of fingers, to bring the wings into the position which would allow the action of the thoracic muscles upon the base of the principal veins. Nevertheless, it is difficult to conceive how this operation can be performed by those species whose forceps are as long as their body.

COOPER'S HELIX IN COLORADO.

BY E. A. BARBER.

AMONG the Helices, there is perhaps no species which presents greater diversity in form, size, and markings, than *Helix Cooperi*. Until recently, our knowledge has been somewhat limited in regard to this beautiful and interesting western species; but our information has been materially increased of late, by the results of the researches of the United States Geological Survey. During the summers of 1874–75, I found great quantities of these shells throughout Colorado, in a variety of locations, and under variable conditions. I first discovered them in Middle Park, a few miles from the Hot Sulphur Springs, or the settlement known as Grand City, on the head-waters of the Grand or Gunnison River. As we were riding along through a severe hail-